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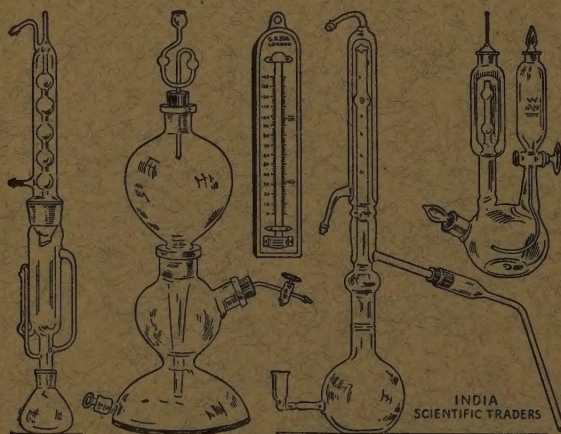
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EDITORIAL

The Journal has now been made the organ of the Society of Animal Morphologists and Physiologists and this is the first number under the new management.

The founder of the journal, Professor C. J. George, having retired from the Wilson College, Bombay, after twenty four years of service dedicated to teaching and research, Dr. J. C. George, of the Maharaja Sayajirao University of Baroda is now entrusted with the Managing Editorship of the Journal and the Hon. Secretaryship of the Society.

We take this opportunity of recording our deep appreciation of the yeoman service rendered by Professor C. J. George for the advancement of zoological studies.

EDITORIAL

The Journal has now been made the organ of the society of Animal Morphologists and Physiologists. This is the first number under the new arrangement.

CONTENTS

CONTENTS

COMPARATIVE MORPHOLOGY OF THE LUNG IN SNAKES WITH REMARKS ON THE EVOLUTION OF THE LUNG IN REPTILES

J. C. George and R. V. Shah

Department of Zoology, M. S. University of Baroda

CONSIDERABLE departure from the generalised condition of the lung in lizards has taken place in the snakes. Apart from the many papers of early workers, George and Varde (1941) have given an account of the modification of the lung in some Indian snakes. Again Varde (1951) has given a comparative account of the structure of the lung in certain snakes. Recently Bellairs and Underwood (1951) dealt with the evolution of the snakes and incidentally also alluded to the modifications undergone by the lung in the snakes. While studying the structure of the chelonian lung (George and Shah, 1954), the lung in some snakes has also been examined for purposes of comparision, and the observations made are given below. It was also considered at this juncture to touch upon the problem of evolution of the lung in reptiles.

Structure of the Lung in Some Snakes

(Figs. 1 & 2)

The bronchus is more extensive in the snakes than in the lizards and the posterior part of the lung is drawn out into a saccular chamber which is devoid of the characteristic pulmonary tissue. The variations in the structure of the lung in the snakes consist in (1) the extent of the saccular portion of the lung, (2) the development of the bronchial portion, and (3) the anterior extension of the functional part of the lung to the tracheal region also. Based on these generalisations, the snakes studied in this connection can be grouped into five categories.

In the first category can be included those snakes like the python which are more cylindrical and both the lungs are well-developed. Commensurate with the more or less symmetrical development of the right and left lung, the lung structure is basically generalised, with the bronchial part well-developed and the saccular part short.

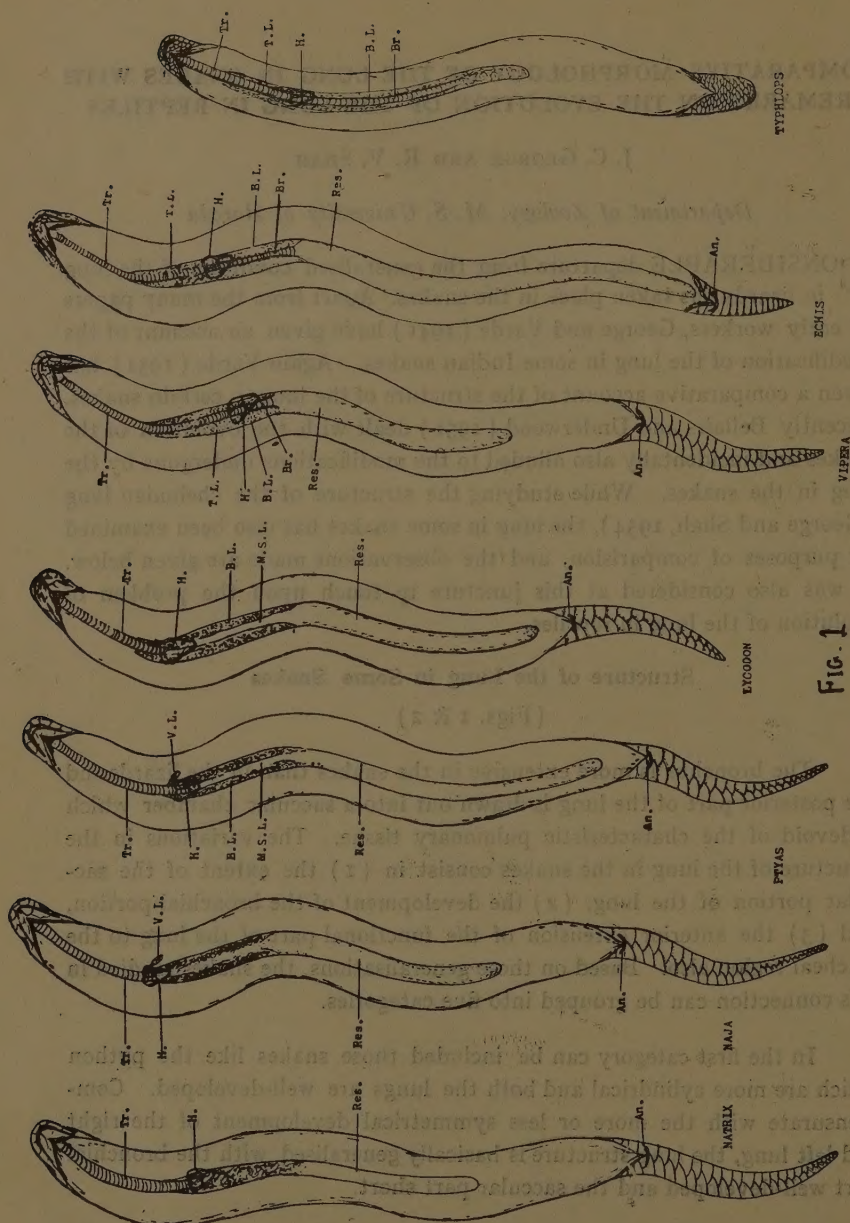In the second category can be included the freshwater snakes like

Fig. I. Diagrammatic sketches showing the respiratory organs of the snakes.
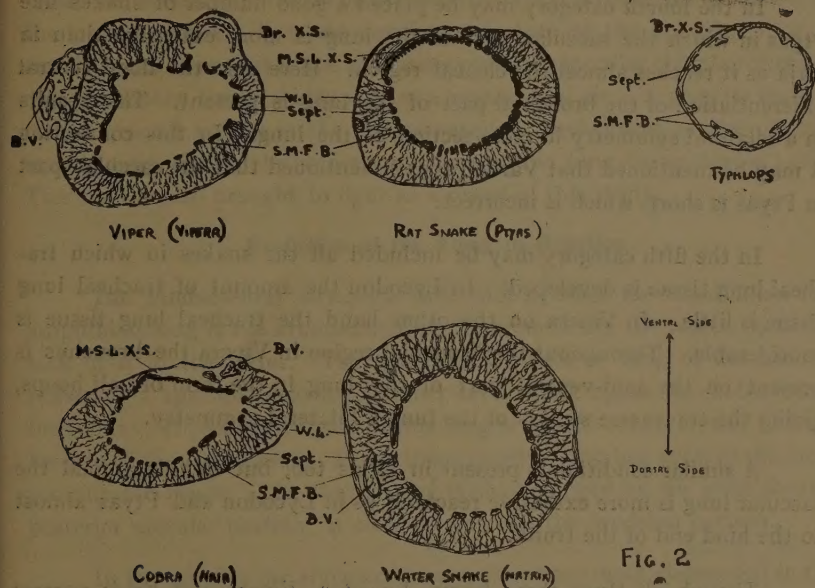
Fig. 2. Camera lucida sketches of the T.S. of the snake lung.
Br. X.S. Bronchus cut transversely showing the cartilaginous half ring; B.V., Blood vessel; M.S.L.X.S., Membranous sheath on the ventral side of the broncheal lung cut transversely; Sept., Septum dividing primary alveoli; S.M.F,B., Smooth muscle fibre bundles; W.L., Wall of the lung.

Natrix in which the saccular part of the lung is well-developed and the lung tissue of the bronchial part is uniformly developed all round the bronchus.

In the third category can be placed a large number of common snakes such as Naja, in which the saccular part of the lung is as well-developed as in Natrix, but the ventral part of the lung lying adjacent to the body wall does not develop lung tissue to any great extent ; so much so that there is a dorsi-ventral differentiation of the bronchial lung. There is in the hind region on the mid-ventral part of the alveolar lung a membraneous connective tissue padding in the place of the incomplete rings of the bronchus, while anteriorly the region is occupied by the bronchus. As a result in a cross-section of the lung a distinct bilateral symmetry is seen. This bilateral symmetry occurs in the lung of all ground snakes.

In the fourth category may be placed a good number of snakes like Ptyas in which the saccular part of the lung is more extensive than in Naja as it reaches almost the cloacal region. Here also the dorsi-ventral differentiation of the bronchial part of the lung is present. This results in a bilateral symmetry in cross-section of the lung. In this connection it may be mentioned that Varde (1951) mentioned that the saccular part in Ptyas is short, which is incorrect.

In the fifth category may be included all the snakes in which tracheal lung tissue is developed. In Lycodon the amount of tracheal lung tissue is little. In Vipera on the other hand the tracheal lung tissue is considerable. Throughout the bronchial region in Vipera the bronchus is present on the mid-ventral part of the lung in the form of half hoops, giving the transverse section of the lung a bilateral symmetry.

A similar condition is present in Echis too, but in this animal the saccular lung is more extensive reaching as in Lycodon and Ptyas almost to the hind end of the trunk.

Though all these three forms, Lycodon, Vipera and Echis possess tracheal lung tissue, the morphology of the lung differs in these three snakes. In the first form the bronchus is not represented by half hoops in the bronchial lung as in Vipera and Echis, but in their place a connective tissue padding occurs. As mentioned before the saccular part of the lung is short in Vipera, but extensive in the other two.

Typhlops is usually included among the snakes, but recently McDowell and Bogart (1954) expressed doubts as to its systematic position and preferred to include it in the Anguinomorpha, a group of Lacertilia. In Typhlops the posterior saccular part of the lung is short as in lizards, but unlike the lizards the bronchus is very extensive and in addition tracheal lung tissue is developed. But the most peculiar aspect of the lung of Typhlops is the very simple nature of the lung tissue. The septa in the lung resemble those of the Amphibia and there is a very extensive central pulmonary chamber. But unlike the amphibians the bronchus is very extensive attached to the ventral wall of the lung with its characteristic half-hoops. Typhlops thus should Le put in a new category.

A more extensive study of the morphology of the lung is required to

assess the extent and nature of the variations met with in the structure of
the lung in snakes.   But one significant feature of the ophidian lung is
clearly brought out ; it is the extensive posterior saccular chamber without
any pulmonary tissue, which acts as a reservoir of air.   A peculiar feature
of the ground snakes is the unsymmetrical development of the charac-
teristic lung tissue, the mid-ventral part of the lung being devoid of it.
This trait is also brought to light as a result of this study.

Evolution of the Lung in Reptiles

The fundamental structural difference between the mammalian and
amphibian lung is the arborisation of the bronchus in the former and the
lack of it in the latter.   The generalised primitive lung of the urodele
possesses a spacious central chamber into which opens the abbreviated
bronchus.   The posterior part of this lung is devoid of the alveoli charac-
teristic of the lung tissue.   From this primitive lung has evolved the more
complicated types.   The anuran lung is characterised by an even shorter
posterior saccular portion ; it closely resembles the urodelan pattern.

In the reptiles the alveolar structure becomes more elaborated in the
lizards, with very little extra development of the bronchus over that of
the urodelan lung.   As a result the central cavity becomes restricted, and
there is a short posterior reservoir which is referred to as the saccular por-
tion of the lung.   In the snakes evolution resulted in the suppression of
the left lung in most, and simultaneously the single lung become more
elongated with the posterior region becoming a saccular reservoir for air.
As mentioned above in ground snakes a dorsi-ventral differentiation of the
alveolar portion of the lung also resulted.   The extension of the bronchus
is a character met with only in some snakes.   Among the snakes dealt
with here this feature is met only in the two vipers and Typhlops.   This
feature of the Typhlops cuts at the root of the suggestion that Typhlops
is an anguinomorphan lizard. So, as regards the extension of the
bronchus and the development of the tracheal lung tissue, the vipers are
an advanced group.   '

In the other two groups of reptiles, Chelonia and Crocodilia the
major trend in the evolution of lung was in the acquisition of an elaborate
bronchial system by arborisation of the bronchus, just as elongation and
sacculation of the posterior part of the lung was the characteristic feature
in the evolution of snakes.   This feature of Chelonia and Crocodilia fore-

shadows the mammalian lung. In the Chelonia the bronchus possesses like the trachea the complete cartilaginous rings unlike in lizards and snakes. Since the whole lung is divided into chambers, alveoli are larger than those of the lizards and snakes and the interalveolar space is filled with smooth muscle and connective tissue. The smooth muscle fibres occur in bundles.

In the Crocodilia, the alveoli are more numerous and consequently small ; it means that arborisation of the bronchii has occurred more extensively in this group, than in the Chelonia.

Summary

1. The variations in the structure of the lung in snakes consist in the extent of the posterior saccular reservoir, of the development of the bronchial part, and in the development of the tracheal lung.

2. On the basis of the variations noted the snakes which form the subject matter of this paper can be separated into five categories.

3. Among the snakes examined only Typhlops, Vipera and Echis the bronchus extends to the bronchial part of the lung. In all the others the bronchus stops short and opens into the central cavity of the lung.

4. The significant trend in the evolution of the lung in snakes had been the differentiation of a posterior saccular portion of the lung.

5. In the ground snakes the characteristic bilateral symmetry of the lung is produced consequent on the non-development of alveolar tissue in the mid-ventral region of the lung.

6. In the evolution of reptiles the primitive generalised lung is met with in the lizards. This type is modified in the snakes through the development of the posterior saccular region which serves as a reservoir. In the chelonians and crocodiles alone the arborisation of the bronchus had occured. This trait has proceeded more in the latter group and consequently their lungs are more spongy and more alveolar, the alveoli being more numerous.

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THE BRACHIAL PLEXUS OF BAT (*PTEROPUS GIGANTEUS*)

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THE brachial plexuses of the commoner laboratory animals have been worked out in full detail by Miller (1934) and those of some of the rarer forms have been described and discussed morphologically by Wilfred Harris (1939). This plexus in a flying mammal, like bat, has certain distinctive features due to adaptive changes in the fore-limb for combining the functions of flying and prehension. The salient points derived from the observations on dissection of six bats are presented and discussed.

Descriptive Observations

The number of cervical vertebrae and nerves is typical of the mammalian class. The complete roots entering into the formation of the brachial plexus are the anterior primary rami of the posterior four cervical and the first thoracic, with supplementing fibres from the primary rami of the fourth cervical and the second thoracic nerves. All the roots are approximately 1 cm. long and abruptly unite to form one thick nerve bundle loosely enclosed in an areolar sheath. It is only by removal of the sheath and careful separation of fibres that the various trunks and divisions can be recognised as components of this nerve bundle.

The fibres from this nerve bundle emerge as two trunks, an anterior (A. T.) and a posterior trunk (P. T.).

The anterior trunk :—The anterior trunk after running for a short distance gives off two dorsal and three ventral branches. The ventral branches consist of an anterior, a middle and a posterior nerve. The anterior nerve proceeds forwards as the suprascapuler nerve (S. Sc.). The middle one (A. H.) proceeds laterally towards the anterior humeral muscles to innervate them. Before reaching the anterior humeral muscles, however, it gives off a branch which uniting with a similar one from the posterior trunk forms a nerve which soon after divides into the lateral cutaneous (L. C.) nerve of the forearm and the median nerve (M).

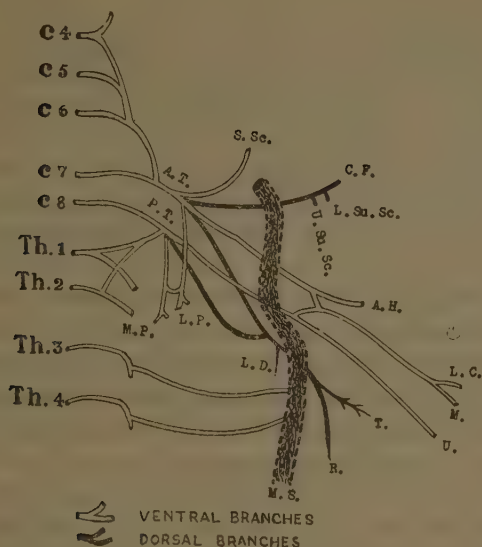The posterior ventral nerve issuing from the anterior trunk proceeds

Fig. 1. Brachial Plexus of *Pteropus giganteus*

Fig. 1—The brachial plexus of the bat (*Pteropus giganteus*)

A. H., Nerve to the anterior humeral muscles; A. T., anterior trunk of the brachial plexus; C. F., curcumflex nerve; L. C., lateral cutaneous nerve of the forearm; L.P., Lateral Pectoral nerve;

L. D., nerve to the latissimus dorsi muscle ;

L. Su. Sc., lower subscapular nerve ; M., median nerve ;

M. S. muscular slip ; M. P., medial pectoral nerve ; P. T., posterior trunk of the brachial plexus; R., radial nerve; S. Sc., suprascapular nerve ; T., nerve to triceps muscle ; U., ulnar nerve ; U. Su. Sc., upper subscapular nerve.

backward as the lateral pectoral (L. P.) nerve. It, however, sends a communicating branch to the medial pectoral (M. P.) nerve which issues from posterior trunk.

The dorsal branches of the anterior trunk constitute two nerves. The anterior of these nerves after proceeding laterally gives off the upper (U.Su.Sc.) and lower (L.Su.Sc.) subscapular nerves. Thereon, it proceeds as the circumflex (C. F.) nerve. The posterior of the dorsal branches of the anterior trunk proceeds postero-laterally and gives off first a nerve (L. D.) to the *latissimus dorsi* muscle. Before giving off this nerve it is joined by the dorsal branch of the posterior trunk. After giving off the nerve to the *latissimus dorsi* muscle, the nerve proceeds for a short

2

distance and then divides into two branches, the anterior (T.) nerve for the triceps muscle and a posterior (R.) radial nerve.

The posterior trunk :—The posterior trunk has a connection with the first thoracic and the first thoracic likewise has a connection with the second thoracic nerve. At its junction with the first thoracic nerve the posterior trunk divides into two ventral nerves and a single dorsal nerve. The dorsal nerve after running for a short while, merges with the posterior dorsal branch of the anterior trunk, which has already been referred to. Of the two ventral nerves, one proceeds laterally which after giving off a branch as already mentioned, towards the formation of the lateral cutaneous and median nerves proceeds as the ulnar (U.) nerve. The other ventral nerve proceeds posteriorly as the medial pectoral (M. P.) nerve. This has a connection as already referred to with the lateral pectoral (L. P.) nerve. The thicker lateral pectoral nerve supplies the clavicular and upper sterno-costal fibres of the pectoralis major. The medial pectoral nerve supplies the lower sterno-costal and abdominal parts of the pectoralis major. The abdominal part of the pectoralis major is fairly well developed and runs high up on the humerus for its insertion. Consequently, the medial pectoral nerve adds to its fibre component by communication from the lateral pectoral nerve.

There is a special bundle of muscle fibres (M. S.) extending from the Coracoid process to the skin on the medial side of the fifth digit. This muscular slip is innervated by the lateral branches of the third and fourth thoracic nerves. This bundle appears to serve the function of securing the neuro-vascular bundle on the medial side of the arm.

Discussion

The position of the anterior limb in relation to the vertebral column and spinal nerves is fixed at the cervico-thoracic junction for all tetrapods. Hence the components of the brachial plexus are invariably derived from the posterior cervical and the anterior thoracic nerves. The composition, pattern and branching of the plexus are however, considerably modified to suit the needs of the individual species.

In the bat a relatively shorter neck affords a wider base to the forelimb and permits a larger number of nerves to take part in the formation of brachial plexus. The same reason accounts for six or seven nerves entering into the formation of the plexus in the Armadillo (Wilfred Harris, 1939).

The lack of adequate distance between the two shoulder-tips and the great freedom needed by the anterior limbs for flying, call for an immediate union of all the nerve roots for segmental, sensory and motor regrouping before branching.   The loose areolar sheath around the thick nerve bundle affords a greater security to the nerves during the complex and precise movements of flight.   A similar sheath is present on the plexus of the agile, acrobatic gibbon (Wilfred Harris, 1939).   In this sheath, however, the nerve fibres lie rather loosely.

The muscles around the shoulder joint are elaborately modified for the complex movements of flight, while in the distal part of the fore-limb the functional components are less differentiated for the simple acts of flexion and extension of the digits.   This specialisation of the shoulder musculature has led to a very complicated pattern of the plexus in the proximal part and a comparatively simpler arrangement of nerves in the distal part of the limb.

A greater use of the pectoral muscles in flight increases their extent on the ventral body wall, yoking more nerves to the lower part of the plexus from where the ventral branches of the brachial plexus arise. It is probably for this reason that this plexus in the bat receives a sizeable contribution from the second thoracic nerve, for ensuring a good supply to the fairly well-developed abdominal part of the pectoralis major. Separate origin of muscular and cutaneous parts of the musculo-cutaneous nerve is a primitive character shared by all sub-mammalian forms and some mammals, like the guinea pig (Agarwal, 1948).

The early separation of the median and ulnar nerves is a definite advance towards physiological independence of the radial and ulnar digital flexors supplied by the two nerves.   These muscles in birds are supplied by the combined medio-ulnar nerve.   This early separation of the two nerves in bat is perhaps due to the fact that the fore-limb has to carry on prehensile function as well, in addition to flight.

The relative independence of the circumflex nerve and its preponderance over the radial nerve is a characteristic of the plexuses of all the animals having a greater utility of the deltoid muscle than the dorsal forearm muscles.   This independence is first noticed in the reptilian plexus and is greatly amlpified in birds and bats.

The dorsal forearm muscles in primates, have taken up the functions of abduction and adduction of the hand in addition to the original function of digital extension. For the supply of this pleurifunctional group of muscles the radial nerve has added more and more dorsal fibres from the anterior roots of the brachial plexus . This culminates in a very much smaller posterior division of the posterior trunk in a human plexus. This generally has a few fibres from the first thoracic nerve and is frequently derived from the eighth cervical nerve only (Gray, 1954).

Summary

1.   The composition, pattern and branching of the brachial plexus of the bat, (*Pteropus giganteus*), has been described.

2.   The presence of an additional protective muscular slip on the medial side of the 5th digit of the fore-limb has been noted.

3.   The characteristics of the plexus and its similarities with the typical avian and mammalian plexuses have been discussed.

4.   In conclusion it is suggested that the functional utility of deltoid and pectoral muscles, respectively, influences the inclusion of nerve roots at the anterior and posterior limits of the brachial plexus. In animals like the monkey, anthrapoid apes and bat, where both the muscles are functionally well developed, a larger number of nerve roots enters into the formation of the brachial plexus.

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THE CRANIAL MUSCLES OF TELEOSTS—1

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IN the adaptive radiation of teleosts the head has undergone many modifications. The modifications of the head have been understood more in terms of its osteology than with reference to the soft parts. For a comprehensive understanding of these modifications, those of the cranial muscles should also be taken into account. It was therefore considered advisable to make a concerted attempt to study the cranial muscles of representative species from the numerous families of teleosts.

There is a good deal of information available to us from the several papers on the cranial musculature of fishes. One of the earliest papers is that of Vetter (1878) which is not available here now. So also the publications of Allis, Luther, Lubosch etc. are not locally available. But contributions of earlier works have been reviewed by Takahasi (1925) and Edgeworth (1935).

Takahasi in his paper had dealt with the cranial musculature of cypriniform fishes, where he has given a comparative study of their cranial musculature with regard to origin, insertion, innervation and the relative positions.

In his illuminating treatise on cranial muscles of vertebrates Edgeworth has dealt with, in a comparative manner, those of various classes of vertebrates and has homologised them. He has also given an account of the muscles employed in opening the mouth. In a separate chapter he has traced the ancestral history of the cranial musculature in vertebrates. Moreover he has given the synonyms of the nomenclature of cranial muscles.

There is some confusion regarding the terminology of cranial muscles. It is not claimed that the one adopted here is by any means the best.

The cranial muscles include the mandibular muscles, the hyoid muscles, the branchial muscles, the cucularis, hypobranchial muscles and

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1   This is the first paper of a series.
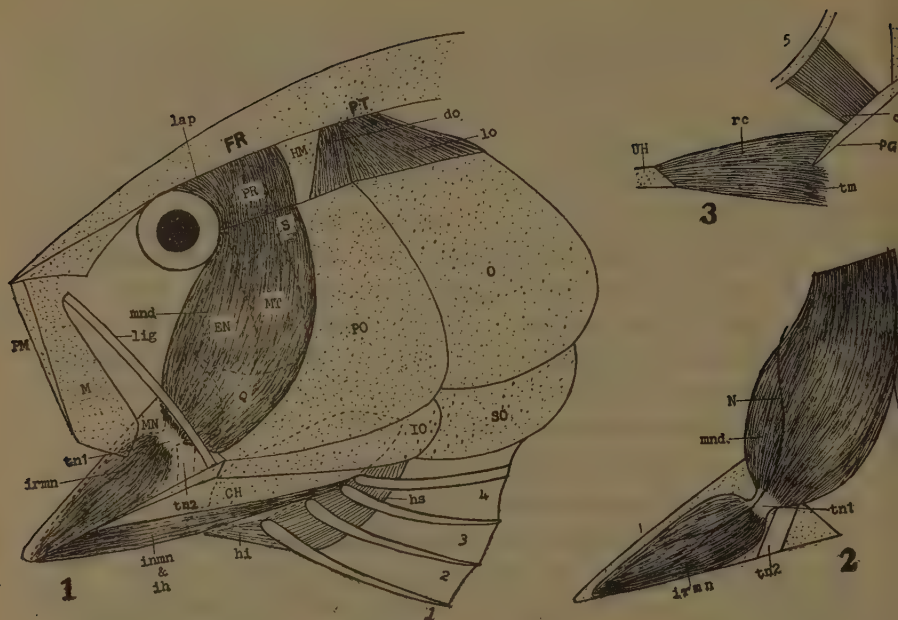
HILSA ILISHA

Fig. 1. Lateral view of the head showing the muscles and the bones. The boundaries of the bones covered by muscles are shown by dotted lines.

Fig. 2. Lateral view showing the tendinous insertion of the *mandibularis* and the insertion and origin of the *intramandibularis*.

Fig. 3. Lateral view showing the origin and insertion of the *coracobranchialis* and the *rectus cervicis*.

aap	adductor arcus palatini	O	Operculum
ao	adductor operculi	ods	obliqui dorsales superior
BR 1-5	Branchial arches	odi	obliqui dorsales inferior
cb	coracobranchialis	PO	Pre operculum
CH	Ceratohyal	PR	Pro otic
do	dialator operculi	PT	Pterotic
EN	Endopterygoid	PA	Parasphenoid
FR	Frontal	PH	Pharynx
hh	hyohyoideus	PG	pectoral girdle
hs	hyohyoideus superior	PM	Premaxilla
hi	hyohyoideus inferior	Q	Quadrate
HM	Hyomandibula	rab	retractor arcuum branchialium
irmn	intramandibularis	rc	rectus cervicis
inmn & ih	intermandibularis & interhyoideus	SO	Sub-operculum
IO	Inter operculum	S	Symplectic
lig	ligament	Spoe	sphincter oesophagi
lo	levator operculi	sr	subarcuales recti
lap	levator arcus palatini	sc	subarcuales communis
lab	levator arcus branchialis	tn1	tendon of mandibularis (dorsal)
M	Maxilla	tn2	tendon of mandibularis (ventral)
MN	Mandible	tv 4 & 5	transversi ventrales
mnd	mandibularis	tm	trunk muscle
MT	metapterygoid	UH	Urohyal
N	Nerve	1, 2, 3 & 4	Branchiostegial rays.

the eye muscles.   The last group of muscles is not generally modified and as such they are left out in this survey.

The mandibular muscles are split into the *adductor mandibulae*, the *constrictor dorsalis* and the *inter-mandibularis*.   The *adductor mandibulae* usually is separated into the *maxillaris*, the *mandibularis* and the *intra-mandibularis*.   In some teleostei one or two of these parts are lacking. The *constrictor dorsalis* is separated into the *levator arcus palatini*   In very rare cases the *dialator operculi* is wanting.
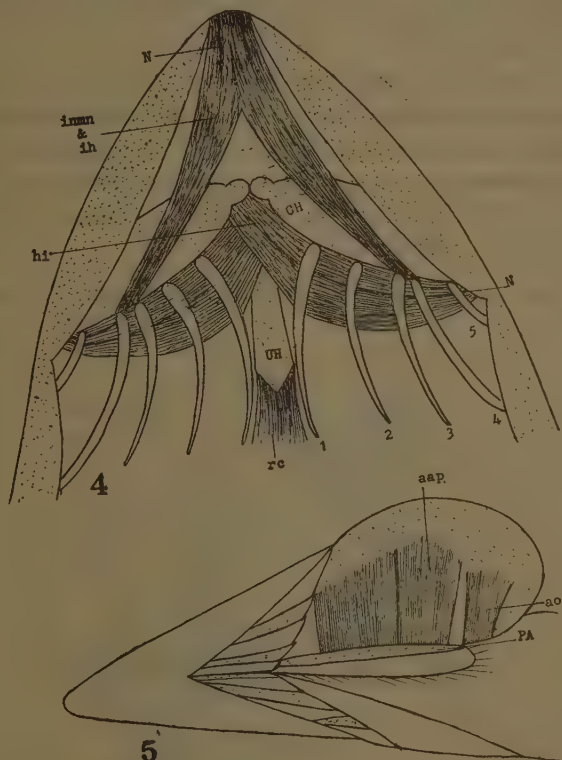
HILSA ILISHA

Fig. 4   Ventral view of the head showing the origin, insertion and the innervation of the fused *intermandibularis* and the *interhyoideus,* the *hyohyoideus* and the insertion of the *rectus cervicis.*

Fig. 5.   Internal view of the head showing the origin and the insertion of the *adductor arcus palatini* and the *adductor operculi.*
Abbreviations as in figs. 1, 2 & 3

The hyoid muscles are split into the *adductor arcus palatini*, the *adductor operculi*, the *levator operculi*, the *interhyoideus* and the *hyohyoideus*.

The branchial muscles consist of the *levatores arcuum branchialium*, the *coracobranchialis*, the *subarcuales recti* and the *transversi ventrales*. A *cucullaris* is developed in some of the teleostei.

The *transversi dorsales*, the *obliqui dorsales* and the *retractor arcuum branchialium* are developed from the *sphincter oesophagi*.

The *rectus cervicis* is the only muscle developed from the hypo-branchial muscles in teleostei.

There is a membrane developed in the head region which connects the maxilla with the mandible and also the maxilla with the *mandibularis*. In some fishes the extent of the membrane becomes restricted due to the greater development of the *mandibularis* and or *maxillaris*. In some cases a ligament is developed on this membrane which connects the bases of the maxilla and mandible.

The cranial muscles of a few representative species of Indian fishes are described.
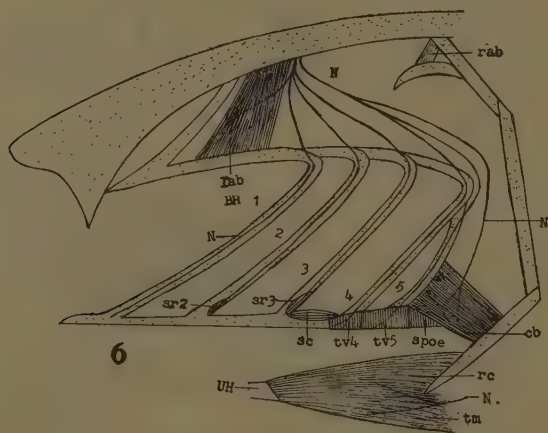
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Fig. 6. Diagrammatic view showing the origin, insertion and innervation of the *levatores arcuum branchialium*, the *subarcuales recti*, the *subarcuales communis*, the *transversi ventrales*, the *rectus cervicis*, the *coracobranchialis* and the *retractor arcuus branchialium*.

Abbreviations as in figs. 1, 2 & 3.

SUPER FAMILY CLUPEOIDE
FAMILY CLUPEIDÆ
HILSA ILISHA (Ham)
The Mandibular Muscles

The *adductor mandibulae* consists of only the *mandibularis* and the *intramandibularis*, the *maxillaris* being absent.

The *mandibularis* Figs. 1, 2 mnd

Description :—The *mandibularis* is a broad sheet of muscle. The origin of the muscle is fleshy and towards the insertion the anterior ventral tip of the muscle resolves into two tendons (Fig. 2, tn_1 & tn_2) ; one tendon (tn_1) arises from its anterior dorsal tip, while the other (tn_2) arises from its ventral part. There is a ligament, lying anterior to the muscle, developed from the membrane lying in between the maxilla and the *mandibularis* which connects the bases of the maxilla and mandible. It is not known if it is derived from the muscle.
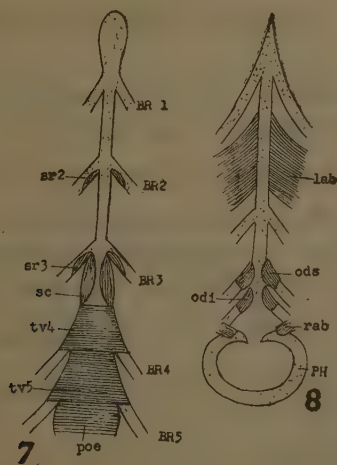
HILSA ILISHA

Fig. 7. Ventral view of the branchial arches showing the origin and insertion of the *subarcuales recti*, the *transversi ventrales* and the *subarcuales communis* and the origin of the *sphincter oesophagi*, (poe).

Fig. 8 Dorsal view of the branchial arches showing the origin and the insertion of the *obliqui dorsales* and the origin of the *levator arcuum branchialium*.

Abbreviations as in figs. 1, 2 & 3

Origin :—It originates in a fleshy attachment from the ventral part of the pro-otic, the anterior ventral corner of the hyomandibula, the symplectic. the whole length of the preoperculum and the quadrate. It runs anteriorly downwards covering the metapterygoid and the posterior part of the endopterygoid.

Insertion :—On the one hand the muscle is inserted by fleshy attachment on the posterior part of the mandible and on the other hand it is resolved into tendons. The dorsal tendon (tn_1) is continued as the *intramandibularis* (Fig. 2 irmn) and the ventral tendon (tn_2) is inserted on the inner posterior part of the mandible.

Innervation :—A branch of the N. *mandibularis V* passes above the muscle and innervates it. The mandibular branch of the N. *hyomandibularis VII* also gives out a branch to the muscle.

Action :—It helps in drawing the mandible up.

The *intramandibularis*. Figs. 1 & 2, irmn.

Description :—The muscle is fusiform in shape lying internal to the mandible.

Origin :—It arises from the upper tendon (tn_1) of the *mandibularis* and runs on the inner side of the whole length of the mandible.

Insertion :—It is inserted on the inner ventral border of mandible.

Innervation :—The N. *mandibularis V* which innervates the *mandibularis* runs downwards and after passing along the tendon tn_1 divides into two and innervates the dorsal and ventral parts of the muscle.

Action :—It assists the action of the *mandibularis*.

The *constrictor dorsalis*. It is divided into the *levator arcus palatini* and the *dialator operculi*.

The *levator arcus palatini*. Fig. 1. lap

Description :—It is a broad sheet of muscle lying dorsal to the *mandibularis*.

Origin :—It arises in a fleshy attachment from the frontal, and descends down to the pro-otic and anterior part of the hyomandibula.

Insertion :—Its insertion on the hyomandibula and pro-otic is fleshy.

Innervation :—The muscle is innervated by a branch of N. *maxillomandibularis V*.

Action :—It fills the concavities of the pro-otic and the anterior part of the hyomandibular bone to give shape to the side of the head.

The *dialator operculi*.   Fig. 1.   do

Description :—It lies posterior to the *levator arcus palatini*.

Origin :—It originates in a fleshy attachment from the post frontal, behind the origin of the *levator arcus palatini* and descends down to the pre-operculum.

Insertion :—It is inserted on the dorsal part of the pre-operculum, without forming a tendon.

Innervation :—This is also innervated by the nerve which innervates the *levator arcus palatini*.

Action :—It assists in lifting the operculum.

The *intermandibularis*.   Figs. 1 & 4 inmn & ih

Description :—This muscle is fused with the *interhyoideus* to form a single muscle.

Origin :—The fused muscle on each side originates forming a fleshy attachment from the outer ventral part of the ceratohyal and the anterior tips of the third and fourth branchio-stegial rays.   It runs forward and meets its fellow from the other side to form one broad sheet of muscle.

Insertion :—The fused muscle is inserted on the anterior tips of the two rami of the lower jaw without forming any tendon.

Innervation :—The anterior part of the muscle is innervated by a branch of the N. *mandibularis V* and the posterior is innervated by the mandibular branch of the N. *hyomandibularis VII*.   As the muscle is fused with the *interhyoideus*, the hyoideus branch of the N. *hyomandibularis VII* also gives out a branch to the muscle.

Action :—It helps in depressing the lower jaw and also forms the floor of the mouth cavity.

The Hyoid muscles

The *adductor arcus palatini.* Fig. 5 aap.

Description :—Only two portions of the muscle *viz* : those inserted on the pterygoid and the hyomandibular are developed, the palatine portion of the muscle being absent.

Origin :—It originates in a fleshy attachment from the parasphenoid and runs outward and downwards.

Insertion :—The pterygoid portion of the muscle is inserted on the inner side of the pterygoid and the hyomandibular portion is inserted on the inner side of the hyomandibula. Both the insertions are fleshy.

Innervation :—It is innervated by a branch arising from the trunk of the seventh nerve at its proximal region.

Action :—It forms the roof of the mouth.

The *adductor operculi.* Fig. 5 ao

Description :—It starts as a narrow muscle and as it runs down it becomes broad. It lies inner to the *levator operculi.*

Origin :—The muscle originates in a fleshy attachment from the inner side of the pterotic.

Insertion :—It is inserted without forming any tendon on the inner side of the dorsal part of the operculum just ventral to the insertion of the *levator operculi.*

Innervation :—It is also innervated by the branch of the seventh nerve which goes to the muscle *adductor arcus palatini.*

Action :—It helps in closing the opercular opening by drawing the operculum close to the head.

The *levator operculi.* Fig. 1, lo

Description :—It is a broad thin sheet of muscle lying on the dorsal border of the operculum. It lies behind the *dialalor operculi* and external to the *adductor operculi.*

Origin :—It originates in fleshy attachments partly from the hind region of the hyomandibula and partly from the outer side of the pterotic.

Insertion :—It is inserted on the dorsal part of the operculum dorsal to the insertion of the *adductor operculi*, without forming any tendon.

Innervation :—It is also innervated by the branch of the seventh nerve which goes to the two muscles described above.

Action :—It assists the *dialator operculi* in widening the opercular opening by lifting the operculum.

The *hyohyoideus* Figs. 1, 4 hs, hi

Description :—The muscle is feebly developed. The dorsal part of the muscle is called the *hyohyoideus superior* (hs) which lies inner to the branchiostegial rays and the ventral part is called the *hyohyoideus inferior* (hi) which has connection only to the first member of the branchiostegial rays. The inferior is a narrow piece of muscle.

Origin and insertion :—The superior originates from the posterior outer part of the ceratohyal and the epihyal and is inserted on the first branchiostegial ray, while the inferior originates from the first branchio-stegial ray and runs forward, then the left inferior muscle passes below the right and the right passes above the left and each one is inserted on the opposite hypohyal. Both the origin as well as the insertion are fleshy.

Innervation:—The hyoideus branch of the N. *hyomandibularis VII* passes through the pre-operculum and innervates the hyohyoideus muscles.

Action :—These muscles help in spreading out the branchiostegial rays.

The Branchial muscles

The *levatores arcuum branchialium.*   Figs. 6 & 8 lab

Description :—This is a sheet of muscle poorly developed. The typical bundles present in others in this case are fused together to form a broad thin sheet which suspends the branchial arches to the parasphenoid.

Origin :—It originates as a thin broad sheet from the parasphenoid in a fleshy attachment.

Insertion :—It is inserted on the fused pharyngeo-branchials of the branchial arches without forming any tendon.

Innervation :—It is innervated by the post-trematic nerve of the IXth.

Action :—It assists in lifting the branchial arches.

The *coracobranchialis*.   Figs. 3. 6 cb

Description :—It is a single thin broad sheet of muscle.

Origin :—The muscle originates from the pectoral girdle in fleshy attachment.

Insertion :—It is inserted on the fifth branchial arch, without form-ing any tendon.

Innervation :—It is innervated by a branch of the post-trematic nerve of the Xth.   (Fig. 6. n)

Comparison :—The muscle is not separated into two fasiculi, the externus and internus as in the case of some other teleostei.   The *sub-arcuales recti*. Fig. 6, 7 sr, sc

Description :—They are only two pairs in number, occurring in seg-ments 2nd & 3rd.   They are poorly developed.   In the fourth they exist as the *subarcuales communis* (sc).

Origin and insertion :—The *subarcuales recti* originate from the hypo-branchials of the second and third branchial arches and are inserted on the basibranchials ; the *subarcuales communis* arises from the hypobranc-hial of fourth, runs forward and is inserted on the hypobranchial of the third.   The origin and insertion in both cases are fleshy.

Innervation :—The muscles are innervated by the corresponding branches of the post-trematic nerve (Fig. 6 N).   The nerves pass along grooves on the corresponding branchial arches and innervate the muscles.

Action :—They assist other muscles in lowering the ventral part of the branchial arches.

Comparison :—The muscles are not developed in all arches.   In the first and fifth they are absent.

The *transversi ventrales* Fig. 6, 7 tv

Description :—They are developed only in the branchial segments four and five and in others they are absent.   They are poorly developed. The posterior one is continued as the *sphincter oesophagi*

Origin and insertion :—In the fourth and fifth branchial segments

the *transversi ventrales* originate from the corresponding hypobranchials, run inwards and meet their fellows from the opposite side and fuse to form complete sheets of muscles lying in-between the hypobranchials of the fourth and fifth segments on the ventral side of the pharynx, Both origin and insertion are fleshy.

Innervation :—These are innervated by the branches of the post-trematic nerve of the Xth.

Action : —They also assist the other muscles in drawing the ventral part of the branchial arches down.

Comparison :—They are not developed in all branchial segments and those formed are poorly developed.

The *cucullaris*—not developed.

The *sphincter oesophagi*. Figs. 6, 7 Spoe

Description :—It is not developed on the dorsal side of the oeso-phagus but only on the ventral side.

Origin :—It originates from the last *transversi ventrales*.

Innervation :—Innervated by the branch of the post-trematic nerve of the Xth.

Comparison :—The dorsal and the lateral parts of the muscle are not formed.

The *transversi dorsales* are not developed.

The *obliqui dorsales*. Fig. 8 ods & odi

Description :—The muscles are poorly developed and each one is separated into superior and inferior.

Origin and insertion :—They arise from the anterior parts of the third and fourth epibranchials and are inserted on the posterior part of the same epibranchials. The origin and insertion are both fleshy.

Innervation :—They are innervated by the branches of the post-trematic nerve of the tenth.

Action :—It assists the action of the *levatores arcuum branchialium*.

Comparison :—Poorly developed.

The *retractor arcuum branchialium*. Fig. 8. rab

Description :—This is a single pair of muscles which are poorly developed.

Origin and insertion :—They originate in a fleshy attachment from the dorsal side of the pharynx, run outwards and upwards and are finally inserted on the ventro-lateral parts of the basioccipital.

Innervation :—They are innervated by the same branches of nerves which innervate the *obliqui dorsales*.

Action :—They suspend the oesophagus to the basioccipital.

Comparison :—Only one pair is developed.

The Hypobranchial Muscles

The *rectus cervicis*.   Figs.   3, 4 & 6 rc

Description :—The two muscles from both the sides meet on the mid ventral line, in the anterior-most region of the body, and fuse together to form a single piece of muscle which also fuses with the anterior region of the trunk muscle (tm).

Origin and insertion :—Each one originates from the ventral part of the pectoral girdle ventral to the origin of the *coraco-branchialis*, runs forward and downward to meet its fellow from the other side, and finally to fuse together and afterwards also with the body muscle.   The combination is inserted ultimately on the posterior part of the urohyal.   Both origin and insertion are fleshy.

Innervation :—It is innervated by the occipito-spinal nerve.

Action :—The contraction of these muscles makes the mouth open wide, the operculum to open, the lower part of the branchial arches to straighten a bit and also to open the first two gill slits to a certain extent.

Comparison :—The muscles are well developed.

Acknowledgement

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THE POST-CRANIAL OSTEOLOGY OF *UROMASTIX HARDWICKII* (GRAY)

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I N an earlier publication (George, 1955) a description of the skull of the lizard *Uromastix hardwickii* was given, while the rest of the skeleton is treated in the present one.

The Vertebral Column (Fig. 1 A & B)

The cervical region of the vertebral column consists of eight verte-brae as is the case in most *Lacertilia*. The thoracicolumbar region comprises sixteen vertebrae and the sacral of two, while the caudal consists of a varying number between twentyfour and thirty. All the vertebrae are procoelous.

It has been pointed out by El-Toubi (1949) that the report that *Uromastix spinipes (U. aegyptia)* possesses only seven cervical vertebrae as mentioned by Gadow (1933), is not correct, the correct number being eight. The first four cervical vertebrae in *U. hardwickii* do not bear ribs as in *U. aegyptia* (El-Toubi, 1949), *Agama stellio* (El-Toubi, 1947), *Scincus scincus* (El-Toubi, 1938), *Calotes versicolor* (Iyer, 1942) and *Varanus monitor*, while in Lacerta the last five cervical vertebrae and in Tupinambis (Reese, 1923) and some other *Lacertilia* (Camp, 1923) all the cervicals except the first two bear ribs (Reese, 1923). The first six cervicals in *U. hardwickii* possess distinct intercentra (hypapophyses) the first being formed of the ventral part of the atlas, as in *U. aegyptia* (El-Toubi, 1949) and *Calotes versicolor* (Iyer, 1942) occupying the same positions as those in Sphenodon (Goodrich, 1930). These intercentra be-come smaller in size from the anterior to the posterior, the sixth one being the smallest. In *Varanus monitor*, however, the intercentra are present on all the eight cervicals.

The first vertebra, the atlas, is ring-like with a slender mem-branous transverse horizontal ligament in the middle. Ventrally the ring is thicker and better ossified, while in the mid-dorsal line the ossification

is weak.   The cavity above the ligament is occupied by the nerve cord, while into the space below, fits in front the single occipital condyle and behind, the odontoid process of the axis vertebra.   The anterior face of the atlas is provided with a tripartite facet which fits against the tripartite occipital condyle formed by the basioccipital and the two exoccipitals of the skull.

The axis is the largest of the cervical vertebrae. Its neural arch bears a backwardly-elevated neural spine which gets strongly attached above to the neural arch of the atlas in front by means of an anterior process. The neural arch of this vertebra bears anteriorly a pair of anteriorly-directed prezygapophyses for articulation with the atlas and posteriorly, a pair of posteriorly-directed postzygapophyses for articulation with the neural arch of the succeeding vertebrae. The centrum bears a peg-like odontoid process which fits into a corresponding concavity on the posterior face of the atlas below the transverse ligament.

The rest of the cervical vertebrae are all similar in structure except that the last two have no hypapophyses as already stated.   Each has a short centrum with an anterior concavity a pair of processes bearing the prezygapophyses in front and another pair bearing the postzygapophyses slightly behind the neural spine.   The hypapophysis is present on the ventral surface of the centrum.

The thoracic vertebrae are not distinguishable from the lumbar ones, since all the dorsals carry dorsal ribs and have the same structure.   A thoracic vertebra is longish with a poorly-developed neural spine.   The first four trunk vertebrae carry ribs that reach the sternum and so only these may be regarded as true thoracic vertebrae, while the remaining twelve are to be regarded as the lumbar ones with their ribs progressively becoming shorter towards the sacral region.   In *Calotes versicolor* however, there are only fifteen trunk vertebrae (Iyer, 1942).

The sacral vertebrae as mentioned above are two in number which are generally separate from each other, but in some individuals they are fused together at most of the lateral halves of their transverse processes. Complete fusion of the sacrals in some individuals has been noted by El-Toubi in *U.aegyptia* (1949) and *Scincus scincus* (1938).

The caudal vertebrae possess long transverse processes which gradu-

ally decrease in length and size towards the posterior end of the tail, laterally-flattened tall neural spines and all except the first three Y-shaped chevron processes on the ventral side of their centra, the first chevron bone being present between the third and fourth caudals. In *Calotes versicolor* (Iyer, 1942), the first two caudals only are devoid of the chevron bones. In *U. aegyptia*, El-Toubi (1949) came across one specimen in which the first chevron, a poorly-developed one, was present between the second and the third caudals; otherwise in the others this bone was present on all caudals except the first three. Unlike the tail vertebrae of the Geckones and many Lacertae, those of Uromastix do not split in the middle.

The Ribs (Fig. 1 A,B, & C)

There are four pairs of cervical ribs attached to the last posterior four vertebrae, of which the anterior two are short and the posterior two long. Each of these ribs possesses a cartilaginous piece at its free end. They do not reach the sternum.

The anterior four of the sixteen pairs of dorsal ribs are attached to the sternum as in *U. aegyptia* (El-Toubi, 1949). In *Calotes versicolor* (Iyer, 1942) of these four pairs of ribs the posterior two are attached to the stem of the xiphisternal processes. The rest of the dorsal ribs are tipped with cartilage and are free. In *Varanus monitor*, however, the first dorsal rib is free, the second and third are attached to the body of the sternum, while the fourth gets attached to the tip of the xiphisternal process. The last pair of dorsal ribs is free and not fused with the last dorsal vertebra as is the case in *Agama stellis* and other agamids (El-Toubi, 1947).

The Sternum (Fig. 1 C)

The sternum is typically reptilian. It is a shield-shaped imperfectly-ossified plate with a pair of small oval fenestrae in the membranous broad portion, one on either side of the middle line. In some lizards like Chamaesura (Essex, 1927.) and Varanus, the sternum is not fenestrated. Posteriorly the sternum bears a pair of slender xiphisternal horns. In *U. aegyptia* the body of the sternum is not so much pointed posteriorly as in *U. hardwickii* and so the two xiphisternal horns in the former are, rather wide apart, while in the latter they are much closer. The T-shaped inter-clavicle or episternum is fused with the sternum at its anterior extremity. The median arm of this bone extends almost to the posterior limit of the
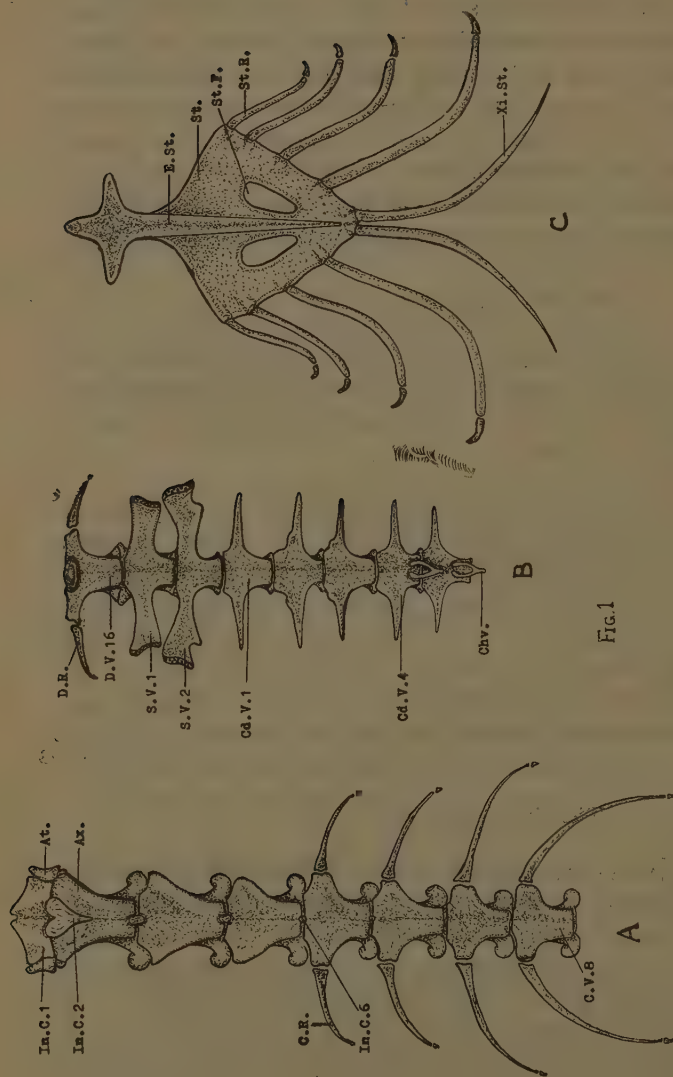
Fig. 1 (A) Ventral view of the cervical vertebrae and ribs.
(B) Ventral view of the last dorsal, two sacral and anterior five caudal vertebrae,
(C) Ventral view of the sternum.

At., Atlas; Ax., Axis; C. R., Cervical rib; C. V. 8, Eighth cervical verterba;
Cd. V. 1 and Cd. V. 4, First and fourth caudal vertebrae: Chv., Chevron bone;
E. St., Episternum; In, C. 1 to In. C. 6, First to sixth intercentra;
S. V. 1 and S. V. 2, First and second sacral vertebrae; St., Sternum;
St. R., Sternal rib; St. F., Sternal fenestra; Xi. St., Xiphisternum.

sternum.   The clavicles are attached by their sternal processes with the anterior part of the episternum.

The Pectoral Girdle (Fig. 2 A)

The pectoral girdle of each side consists of a backwardly directed supra-scapula, a scapula joining with a coracoid in front and a clavicle attaching the coracoid to the episternum in the midventral line. The supra-scapula is not ossified and shows a number of small fenestrae along its outer free border.   It is broader on the dorsal side and gradually narrows towards the ventral side where it meets the scapula which is flattened and ossified.   Towards the midventral plane, the scapula joins the coracoid. The coracoid is a larger, broad, flattened plate which is cartilaginous on its anterior and inner borders.   It possesses two coracoidal fenestrae along its anterior border, the lateral one being larger than the other. According to El-Toubi (1947) there is only one coracoidal fenestra in *Agama stellio*. As a result of the perforations the anterior part of the coracoid bone consists of only two peg-like projections.   At the junction between the scapula and the coracoid there is a shallow groove the glenoid cavity, to accommodate the head of the humerus.   The clavicle is a slender rod-like bone which is attached to the pectoral girdle on its anterior border with its outer tip articulating with a short insignificant process on the proximal part of the supra-scapula and the medial end articulating with anterior end of the inter-clavicle.   In *Calotes versicolor* (Iyer, 1942) and *Varanus monitor* the clavicle articulates with the mesoscapula and does not reach the supra-scapula.

The Anterior Limb   (Fig 2 B)

The humerus is a short massive bone flattened and expanded at the ends.   At the proximal end the expanded head having a cartilaginous cap is somewhat hemispherical in shape and it articulates with the pectoral girdle at the glenoid cavity.   Behind the head the humerus bears an expanded tip which represents the deltoid ridge where the deltoid muscle is inserted.   Distally the expanded end bears the trochlea which shows three partially distinct convex surfaces for articulation with the olecranon process of the ulna and the proximal end (head) of the radius.

In the fore-arm the ulna is larger than the radius and it possesses a bony patella ulnaris at its proximal end.   The ulna extends into an

Fig. 2 (A) Pectoral girdle; (B) Forelimb;
          (C) Pelvic girdle; (D) Hindlimb.
Ac., Acetabulum; C., Centrale; C. F., Coracoidal fenestra;
C. S. F., Coraco-scapular fenestra; Cd ; Coracoid; Cl., Clavicle;
Dc. 1 and Dc. 5, First and fifth distal carpals; Dg. 1 and Dg. 5, First and fifth digits; Dt. 3 and Dt. 4, Third and fourth distal tarsals;
E. Is., Epischium; E. P., Epipubis; F., Femur; Fb., Fibulare; Fi., Fibula;
G. F., Glenoid fossa; H. Is., Hypoischium; Hu., Humerus; I., Intermedium;
I. P. F., Ischio-pubic fenestra; Il., Ilium; Is., Ischium;
Mc. 1 and Mc. 5. First and fifth metacarpals; Mt. 1 and Mt. 5, First and fifth metatarsals; O F Obturator foramen; P., Pubis; P. C., Precoracoid cartilage; P. L. P., Processus lateralis pubis; R., Radiale; Rd., Radius;
S. C. F., Supra-coracoid foramen; S. Sc., Supra-scapula; Sc., Scapula;
Sp. Isi., Spina ischii; Tb., Tibiale; Ti., Tibia; U., Ulnare; Ul., Ulna.

olecranon process which articulates with the humerus. Distally the tip of the ulna is rounded and articulates with the intermedium in front and the ulnare laterally. The radius is accommodated by its base on the medial side of the ulnar base, and a ligament binds the two bones together at this point. The proximal end of the radius is slightly concave to accommodate the convex articular surface of the distal end of the humerus. Distally the radius articulates with the radiale. In addition to the ulnare, intermedium and radiale already mentioned, the carpus consists of the centrale and five digital carpalia. In Lacerta, Parker (1906) mentions the presence of the intermedium between the ulnare and the radiale. The presence of such a bone is also mentioned by El-Toubi (1947) in *Agama stellis* and (1949) in *U. aegyptia* and by Bhatia (1955) in *Varanus monitor*. This bone is also present in *U. hardwickii* but absent in *Calotes versicolor* (Iyer, 1942). On the other hand an accessory carpal bone called the pisiform is present in *Calotes versicolor* (Iyer, 1943) and *Varanus monitor* (Bhatia 1955). It has been pointed out by Camp (1923) that the intermedium which is large in Sphenodon and many fossil reptiles is small and often absent in *Lacertilia*. So the presence of this bone in these lizards other than Calotes may be regarded as retention of a primitive feature. With the absence of the intermedium, the presence of the pisiform in Calotes nevertheless is not to be regarded as an advanced feature in this animal since the presence of the pisiform has been known in early reptiles and even indicated in the amphibian Eryops (Gregory, *et al*, 1923 and Gillies, 1929). Further both the intermedium as well as pisiform are present in Varanus. Distally the row of carpals is succeeded by the metacarpals of the digits. The third and fourth metacarpals are longer than the rest and again of the two, the former being the longest as in *U. aegyptia* (El-Toubi, 1949), *Calotes versicolor* (Iyer, 1942) and other lizards. As for the phalanges the typical lacertilian formula of 2, 3, 4, 5, 3, is present.

The Pelvic Girdle (Fig. 2 C)

The ilium is a short bone with a broad anterior ventrally-directed part which joins the ischium ventrally and pubis anteriorly, and a dorsally directed, flattened and longer process which articulates on its medial surface with the transverse process of the sacral vertebrae. The ilium bears on the crest of the front part mentioned above, a triangular upwardly and laterally directed short spine. The ischium is a flattened plate

narrow at the junction with the ilium and pubis and becoming broader towards its ventral median part. The two ischia meet ventrally in a symphysis. The ischium bears a posteriorly directed blunt spine, spina ischii, on the ventral side. At the junction between the two ischia there is an antero-posteriorly directed median process which shows a linear stream of calcification. The anterior part of the process is known as epi-ischium and the posterior part hypo-ischium. The pubis is a curved bone and is separated from its fellow of the opposite side by a cartilaginous epipubis. More or less in the middle of the pubis at its antero-lateral margin is present a well developed processus lateralis pubis. The three hip bones meet at the acetabulum on the lateral side.

The Posterior Limb (Fig. 2 D)

The femur has a rounded head for articulation at the acetabulum. It bears on the dorsal side a single trochanter analogous to the greater trochanter of the mammals. It slightly curves at its distal half to meet the tibia and fibula. The distal end of the femur presents two condyles for articulation with the tibia and fibula. A small patella tibialis is present. The articulation with the bones of the shank is mainly shared by the tibia, the fibula being joined to the postero-lateral part of the distal end of the femur.

The articulating surface of the head of the tibia is somewhat flat, though the anterior part is slightly depressed and the posterior part slightly elevated. There is a tubercle on the lateral side of the head, for the purpose of attaching the ligamentum patella. The distal end of the tibia presents an articulating surface to meet the fused large tarsal of the proximal row. The fibula is very much reduced in comparison with the size of the tibia, and it also articulates distally with the large tarsal bone mentioned above. The proximal row of tarsalia is represented only by two bones, a large posterior and a small anterior one and the distal row by the third and fourth distal tarsals respectively, the first and second being absent. Such a reduction in the number of the tarsalia is met with in many other lizards *Viz. Tupinambis nigropunctatus* (Reese, 1923), *Varanus salvator* (Goodrich, 1942), *Varanns monitor*, *Calotes versicolor* (Iyer, 1942) and *U. aegyptia* (El-Toubi, 1949). The homology of the large proximal tarsal is doubtful. It is often called tibio-fibulare which gives a wrong impression that it is composed of the tibiale and the

fibulare. Taking the evidences available from the studies on fossil reptiles (Broom, 1921 and Watson, 1913) into consideration, El-Toubi (1949) suggested that this tarsal represents the fused fibulare and intermedium, the tibiale being absent. This suggestion seems quite reasonable. Of the two shank bones tibia is by far the stouter and stronger and most of the weight is on this bone. So it is likely that owing to the pressure exerted through the tibia towards the middle and the inner side of the ankle, the outer (fibulare) and middle (intermedium) tarsals got fused while the inner one (tibiale) was pushed out of the joint and gradually lost. In the case of the forearm, the ulna is stouter and stronger than the radius and more weight is exerted on this bone. So it appears likely that the pisiform bone was pushed out of the joint and in some forms like Uromastix, Agama and Lacerta, it was actually lost.

The metatarsals of the first and fifth digits are short, while those of the others are long, the fourth being the longest. The fifth metatarsal is hollowed out broadly on the ventral side to receive the attachment of muscles. This hooked appearance of the fifth metatarsal is typical of the *Lacertilia*. The phalangeal formula of 2, 3, 4, 5, 4 is also typically lacertilian.

Summary

1. In *Uromastix hardwickii* there are eight cervical, sixteen dorsal and two sacral and twenty four to thirty caudal vertebrae. The vertebrae are all of the procoelous type.

2. The first four cervical vertebrae only do not bear ribs. The intercentra are present only on the first six cervical vertebrae.

3. Ribs are borne by all the dorsal vertebrae. The anterior four pairs of them gain attachment to the sternum.

4. Chevron bones are present on all the caudal vertebrae except the first three.

5. A bony patella ulnaris is present. The carpus consists of nine carpals and the digital formula of the hand is 2, 3, 4, 5, 3.

6. A bony patella tibialis is present. The tarsus consists of three bones, a large proximal one corresponding to the fused fibulare and intermedium, and the third and fourth digital ones. The digital formula of the foot is 2, 3, 4, 5, 4.

7. It is suggested that the fibulare and intermedium got fused together and the tibiale pushed out of the joint and gradually lost, under pressure of the weight exerted through the tibia. Similarly in the case of the forearm it is suggested that under pressure of the weight exerted through the ulna the pisiform was pushed out of the joint and gradually lost in some forms.

Acknowledgment

It is a pleasure to record my thanks to my colleague Dr. R. V. Shah for his assistance in the preparation of the diagrams.

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INHIBITORY EFFECTS OF CERTAIN HALOGEN SALTS
ON MILK COAGULATION BY TRYPSIN

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EFFECTS of some halogen salts on milk coagulation by trypsin has been studied by Seth (1924), Kleiner & Tauber (1934a & 1934b) and Clifford (1935). While similar experiments were being carried out by using the intestinal proteinase of an earthworm, due to an error, two halogen salts were introduced instead of one. This gave results which were contrary to expectation. Further tests were therefore carried out on pancreatic trypsin and the results are given below.

Materials and Methods

For these experiments Nestle's powder milk was used because this gave a more reproducible substrate (Kunitz, 1935). Calcified milk was prepared by the addition of calcium chloride in such M solutions that the concentration of calcium chloride in the milk varied from 0.008 M to 0.5 M.

Using this calcified milk the effects of chlorides, bromides, iodides and fluorides of sodium, potassium and ammonium on milk coagulation by trypsin (Merck) were studied. The concentrations of these salts in the reacting fluids varied from 0.008 M. to 0. 5M. The effects in the case of fluorides could be studied only at lower concentrations of calcium chloride as at higher concentrations the milk curdled even before the addition of the enzyme.

In each of these reacting fluids consisting of calcified milk and a halogen salt, 2% aqueous extract of the enzyme was introduced and the effects of the halogen salts on the rate of coagulation noted. The exact moment of coagulation was determined by the method described in detail by Clifford (1935).

Results

The results are given in Tables I-V. All the experiments carried out have not been reported in these tables, yet they are sufficient to indicate

the nature of the effects of halogen salts on coagulation of calcified ̄milk by trypsin.

It was found that chlorides, bromides, iodides and fluorides of sodium, potassium and ammonium inhibit the coagulation of calcified milk by trypsin, the inhibition increasing with increasing concentrations of the halogen salts.   Inhibition by the various halogen salts occurs nearly to the same extent.

This inhibition was less marked when the concentration of calcium chloride was in the range of 0.015 M to 0.125 M. On the other hand, when the concentration was below and above this range, the inhibition was found to be very powerful, (Table V) the coagulum being not formed even after two hours.   When these latter reacting fluids were boiled on a small flame, milk coagulated immediately.

TABLE No. I

Effects of Chlorides on Coagulation of Calcified Milk by Trypsin
Halogen Salt Added

Calcium Chloride Solution M	Control		Sodium Chloride 0.008 M		Potassium Chloride 0.031 M		Ammonium Chloride 0.125 M		Sodium Chloride 0.5 M	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0.015	1	53	2	2	2	24	3	7	..	..
0.031	1	9	2	20	1	37	3	36	..	..
0.062	1	56	2	36	2	44	2	41	..	..
0.125	3	32	..	..	..	..	..	..	8	41

TABLE No. II

Effects of Bromides on Coagultaion of Calcified Milk by Trypsin
Halogen Salt Added

Calcium Chloride M solution	Control		Sodium bromide 0.015 M		Potassium bromide 0.062 M		Ammonium bromide 0.25 M		Sodium bromide 0.5 M	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0.015	1	45	1	52	2	38	6	41	9	41
0.031	1	12	2	1	3	1	..	..	..	..
0.062	..	..	..	..	..	..	..	..	..	..
0.125	3	31	4	59	..	..	..	..	16	17

TABLE No. III

Effects of Iodides on Coagulation of Calcified Milk by Trypsin
Halogen Salt Added

Calcium Chloride Solution M	Control		Sodium Iodide 0.031 M		Potassium Iodide 0.062 M		Ammonium Iodide 0.125 M		Potassium Iodide 0.5 M	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0.015	1	54	3	20	4	34	8	56	12	39
0.031	1	10	2	22	3	11	5	4	..	..
0.062	1	56	2	31	3	35	4	59	..	..
0.125	3	34	4	22	5	20	5	1	17	55

TABLE No. IV

Effects of Fluorides on Coagulation of Calcified Milk by Trypsin
Halogen Salt Added

Calcium Chloride M Solution	Control		Sodium Fluoride 0.008 M		Potassium Fluoride 0 015 M		Ammonium Fluoride 0.031 M	
	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.
0.015	2	8	2	20	2	29	4	7
0.031	..	..	*		*		*	
0.062	..	..	*		*		*	
0.125	..	..	*		*		*	

* Milk coagulates even before addition of the enzyme.

TABLE No. V

Reversible Effect of Halogen Salts on Coagulation of Calcified
Milk by Trypsin.

1. 0.008 M CaCl$_2$ + Mllk + 0.5 M KBr + Trypsin
2. 0.008 M CaCl$_2$ + Milk + 0.5 M NaCl + do
3. 0.008 M CaCl$_2$ + Milk + 0.25 M NH$_4$I + do
4. 0.008 M CaCl$_2$ + Milk + 0.062 M KF + do
5. 0.25 M CaCl$_2$ + Milk + 0.5 M KI + do
6. 0.5 M CaCl$_2$ + Milk + 0.125 M NaCl + do
7. 0.5 M CaCl$_2$ + Milk + 0.062 M NH$_4$Cl + do

Under the above-mentioned conditions no clot was formed even after 2 hours.
On boiling the above-mentioned fluids, the Milk coagulated immediately.

Discussion

These experiments indicate that whereas a halogen salt by itself
hastens the milk coagulating activity of trypsin, in the presence of calcium
chloride it retards this action. This inhibitory action is especially very
powerful when the concentration of calcium chloride is less than 0.015 M
or more than 0.125 M. In this case the calcified milk does not coagulate
even after two hours but coagulates immediately on boiling.

In other words, this combination of calcium chloride and a halogen salt behaves like urease which according to Tauber (1934) inhibits milk clotting by rennin and trypsin. According to him crystalline urease molecule acts as a protective colloid for the casein system, leading to inhibition of milk clotting. When this added protective colloid is destroyed by boiling, milk clots immediately. The system of calcium chloride and a halogen salt seems to act similarly.

Summary

1. It is found that halogen salts inhibit the coagulation of milk by trypsin in the presence of different concentrations of calcium chloride.

2. Inhibition increases with increasing concentrations of the halogen salts.

3. At concentrations of calcium chloride below 0.015 M and above 0.125 M, the inhibitory effects of halogen salts, even at low concentrations, are very powerful, a coagulum of the milk not being formed even after two hours. However, when boiled it coagulates immediately.

4. A suggestion has been made to explain the inhibitory effects.

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EXAMINATION OF GASTRIC SECRETORY FUNCTION WITH TUBELESS METHOD AND ITS COMPARISON WITH THE STANDARD INTUBATION METHOD

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MOST of our information regarding gastric response and function has been derived from work on animal or on human subjects with fistulae. Direct visualization of the gastric mucosa is made possible after the introduction of the gastroscope. Some observations regarding the evacuation time of meals were made fluoroscopically after adding barium to the former. Our knowledge on this subject has been more or less based on roentgen ray observations or the study of individuals with gastric fistulae or otherwise traumatized. A stomach with a fistula, however, is not a normal stomach.

The method of gastric analysis which was in vogue clinically for years entailed the feeding of a standard test meal, the removal of the complete stomach contents at the end of a one-hour period and the analysis of the material so removed. That this method was inaccurate had been repeatedly demonstrated by Rehfuss (1914). Rehfuss (1914) introduced the method known as fractional gastric analysis for the examination of the secretory functions of the stomach. After completely evacuating the fasting juice, a test meal of an oatmeal gruel or alcohol (50 cc. 7% ethyl alcohol) is given and samples of the gastric juice are withdrawn periodically and examined. This method, since its introduction, has been adopted as a standard method and is widely used.

The intubation method, however, has two major disadvantages. Even with expert hands, the introduction of the tube often proves distressing to the subject and the act of swallowing the tube tends to alter the composition of the juice. The most important information which the clinician wants from a gastric analysis is the ability or otherwise of the organ to secrete hydrochloric acid. Recently the utilization of the cation exchange indicator " Diagnex "* has been suggested by many workers as

* Product of E. R. Squibb & Sons.

a method for determining the presence or absence of free hydrochloric acid in gastric contents without the need for gastric intubation, and they have reported their experiences with this test (Segal, Miller and Morton 1950; Segal, Miller, Morton and Young 1950 ; Segal 1951 ; Malach and Banks 1952; Segal, Miller and Morton 1953; Flood, Jones, Rotton and Schwarz 1953 ; Conway and Meikle 1953, and Polland, Carballo and Bolt 1954). After going through the literature it was found that not much data was available on the results of the tubeless method for gastric examination employed in Indians. Work was therefore conducted in this departmental laboratory to find out the results of the use of this test in some normal subjects as well as in patients with achlorhydria and to correlate the findings obtained with the results of the standard intubation method of fractional gastric analysis using alcohol or histamine meal in the same subjects. The results have been set forth here in this paper.

Rationale

Starting with the resin "amberlite XE-96" which has the general

formula $R - (C \overset{\nearrow O}{\underset{O - H}{}} +)_n$ a cation exchange indicator compound,

now marketed under the trade name of " Diagnex ", was produced by replacing the hydrogen ions of the carboxylic acid groups with quininium ions. In the presence of free hydrochloric acid, the hydrogen cation of the acid replaces the quininium cation releasing quinine. The quinine is absorbed in the small intestine and approximately one-third is excreted in the urine (Goodman and Gilman, 1941). This test is then based on the quantitative estimation of quinine in urine.

Material and Method

In conducting the test the following procedure was carried out. The subjects or the patients none of whom had been ingesting vitamins in form of drugs or drugs containing calcium, magnesium, iron or alluminium, during the previous 24 hours, were instructed to observe an 8-hour fast period. On rising in the next morning the bladder was emptied and the urine discarded. No break-fast was allowed. The subject was given 200 c.c. of water containing caffeine.* This was followed by another dose of water. One-hour later urine was collected and the entire quantity was saved in

* 250 mg. caffeine sodium benzoate.

the labelled bottle as " Urine control."   Granules of " Diagnex " were put
into a glass and 100 c.c. of water added.   It was stirred vigorously and
given immediately to be drunk.   This was followed by a dose of water.
At the end of one hour and also after two hours after taking the dose of
" Diagnex ", urine collections were made and the entire quantity of each
was saved in bottles labelled as urine sample 1 and urine sample 2 respect-
ively.   Each time the bladder was emptied as far as possible completely.
If it was found necessary for the subject to void before the specified time,
he was instructed to save the urine and add it to the urine passed at the
time scheduled.   The volumes of all the three urine samples were noted
and an aliquot sample of each was estimated for its quinine content by
the ether-sulphuric acid method of Kelsey and Geiling (1942).   The final
acid extracts were compared with a standard solution of quinine sulphate
in Lumetron fluorophotometer.   The natural fluorescence of the control
urine (expressed as μg. of quinine) and the amount of quinine in each
hourly specimen were calculated.   The two hours total was found out by
adding the urinary fluorescence at the 1st and 2nd hour and then subtract-
ing that of the control from it.

Eighteen persons have been investigated.   Intubation studies were
performed 24 hours before the " Diagnex " test in all by the standard
fractional gastric analysis method using 7 c.c. 50% ethyl alcohol.   Out of
these 18 persons ten were normal subjects (male medical students) of
age between 18 and 22 years and 8 were patients of age varying between
16 and 52 years, admitted in the wards of Shri Sayaji General Hospital,
Baroda, for their complaints of gastric troubles.   Amongst the patients
three were females and the rest were males.   For assessing the results of
the " Dignex " test, these persons have been grouped as belonging to
3 categories namely (1) achlorhydric, (2) isochlorhydric and (3) hyper-
chlorhydric based on the acid response obtained after the alcohol meal
according to the classification given by Napier, Chaudhari and Rai-Chau-
dhari (1938).

Results

The results have been shown in the table and are represented
graphically in the chart given below.   In the group 1 the total urinary
output of quinine in the first two hours after the administration of
" Diagnex " ranged from 16 to 63 mcg. with an average of 38.0 mcg. The
corresponding range in group 2 was found to be 111.8 to 390 mcg. with an

average of 285.4 mcg., while in the 3rd group it ranged from 433 to 676 mcg. with an average of 502.0 mcg. The graph shows the wide separation between the mean curves of the urinary fluorescence at all the stages of 1st hour, 2nd hour and the two hour total, in the three groups. There is not much difference, however, in the three groups in the control urine sample.

Table showing the average urinary fluorescence of experimental subjects in mcg.

Group	1 Hour	2 Hour	Control	2 Hour	Total
1. Achlorhydria (no free HCl)	54.0	19.6	35.7	38.0	
2. Isochlorhydria (highest free HCl. in cc.N/10 acid %, between 1 to 65)	161.0	148.5	48.9	285.4	
3. Hyperchlorhydria (highest free HCl. in cc. N/10 acid %, more than 65)	293.0	251.4	42.9	502.0	
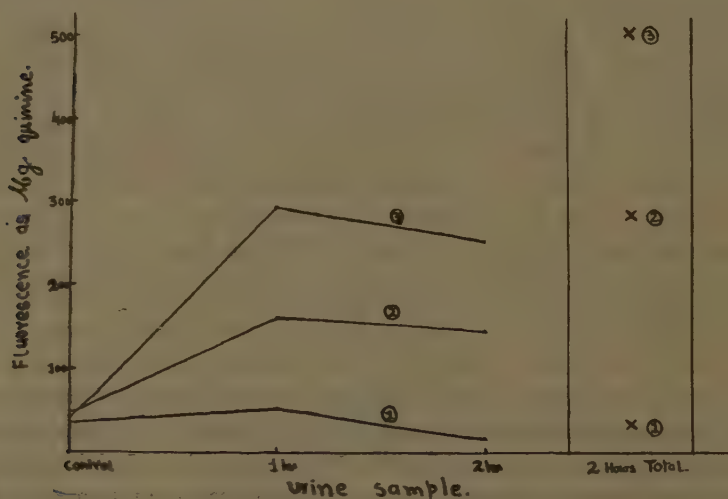
Fig. 1. Graph showing mean fluorescence in urine.

Discussion

Achlorhydria

In the present series of cases, the existence of achlorhydria coincided with an excretion of 63 or less than 63 mcg. of quinine in the total two hour urine. The existence of achlorhydria in all the cases mentioned was confirmed with the histamine test meal examination for the following reason. In the present investigations, out of 9 subjects who had shown achlorhydric response with alcohol meal, three showed on subsequent occassions isochlorhydric or even hyperchlorhydric response with histamine test. This observation therefore once again proves the necessity of performing the fractional gastric analysis examination with histamine test before labelling the cases as belonging to achlorhydria based on results of alcohol test meal only.

Conway *et al* (1953) had stated after their study of the " Diagnex " test in 22 patients that achlorhydria was associated with an output of less than 20 mcg. of quinine in the total 2 hour urine sample. Flood *et al* (1953) had given the upper limit of urinary quinine in the achlorhydric cases as 25 mcg. Segal *et al* (1950) had concluded that a firm diagnosis of achlorhydria depended on an excretion of not more than 15 mcg. of quinine. Our figures are higher than those quoted above. These differences in the interpretation of the significant urinary quinine level possibly be due to variations in the extraction technique or perhaps due to the difference in the amount of quinine contained in the different samples of " Diagnex ". No information is available regarding the quinine content of the preparation. We have, however, estimated the quinine content in the 2.0 gm. dose of material (which actually weighed 2.061 gm.) as 23.75 mg. There are no other figures available for comparison.

Isochlorhydria and Hyperchlorhydria

The existence of isochlorhydria (all three, namely low, medium and high, taken together) corresponded with an excretion of quinine ranging between 111.8 mcg. to 390.0 mcg., while the corresponding range for the hyperchlorhydric subjects was 433 to 676 mcg. Here again the figures obtained are higher than the upper limit given by other workers. Conway *et al* (1953) had obtained a range of 57 to 319 mcg. in his 2nd group of 8 cases in whom free HCl was believed to be present in fair amounts though no actual figures for the quantity of the gastric acidity have been given by

the authors. In the present series of 7 subjects with isochlorhydric response and 5 subjects with hyperchlorhydric response, the highest free acidity ranging between 20 to 58 cc. N/10 acid % and between 65 to 106 cc. N/10 acid % was found respectively after the administration of alcohol as the test meal.

It will be observed from the table and the graph given that the total 2-hour urinary levels of quinine in these cases coincided well with the acidity readings and three distinct curves for the former have been obtained for the three corresponding groups, of achlorhydria, isochlorhydria and hyperchlorhydria.

In the mean curve of urinary fluorescence given by Conway *et al* (1953) the urinary quinine has been shown to be more in the 2nd hr. sample than in the 1st hr. sample. In the present series, however, there is not much difference in the excretion of quinine at the 1st and 2nd hr. period. The two levels are almost equal or perhaps there is a tendency towards a fall rather than a rise. In the few individual cases, however, where the peak of free acidity was found to reach at the end of 2 hours or later, the 2nd hour urine sample gave a higher reading for output of quinine than the 1st hr. sample of urine.

Polland *et al* (1954) had concluded that their grading of the levels of urinary quinine in terms of zero to trace, one plus, two plus etc. could not be well correlated with the gastric acidity. This study shows as can be seen from the graph that more or less a quantitative relationship could be established between the gastric acidity and the excretion of quinine, provided the urinary excretion levels of the latter are estimated quantitatively. Of course it must also be admitted here that more data will have to be obtained in the different types of cases before a definite criterion for judging the gastric secretory function on the basis of the " Diagnex " test can be given. And then in that case this test will not only be serving the purpose as an aid for determining the absence of free HCl. but also may prove useful for giving us quantitative information of gastric secretory function.

Summary

(1) Eighteen persons have been used for determining quantitatively their gastric secretory function with the help of the " Diagnex " test.

(2) Three mean curves for urinary fluorescence as mcg. of quinine are obtained corresponding to the three types of the gastric response, namely (1) achlorhydria, (2) isochlorhydria and (3) hyperchlorhydria, as judged after the fractional gastric analysis examination.

(3) The total two hour urinary quinine in the above three types ranged between 16 to 63 mcg , 111.8 to 390 mcg. and between 433 to 676 mcg. respectively.

(4) The existence of achlorhydria confirmed by the histamine meal test coincided with an excretion of 63 or less of quinine, while the presence of free HCl. was associated with more than 112 mcg. of quinine.

(5) The values obtained have been compared with those of other workers and the significance of this test has been discussed.

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THE SEASONAL VARIATION IN THE FAT CONTENT OF THE LIVER AND GONADS IN A MARINE AND A FRESH WATER DECAPOD

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The vertebrate liver has several functions and one of them is the metabolism of fat. Very little, however, is known regarding the part played by the corresponding organ called the liver or hepatopancreas in the metabolism of fat in the crustaceans.

George and George(1944) noted the general occurrence of fat in the hepatopancreas of crustaceans and also recorded some of the properties of the fat obtained from the liver of the crab, *Paratelphusa guerini*. George and Desai (1954) studied the seasonal variation in the fat content of the liver in the pond snail, *Pila globosa*. The present paper records the seasonal variations in the fat content of the liver and gonads obtained from a number of specimens of the spiny lobster, *Panulirus polyphagus* and the prawn, *Palaemon carcinus* in the year 1954-'55.

Material and Method

The liver and gonads were removed from several male and female specimens separately, weighed, and then dehydrated in an oven at a temperature of 105°C. The water content was determined by substracting the weight of the dehydrated material from the original weight. The fat content was calculated on the fresh weight of the liver and gonads. The fat was extracted from the dehydrated material by using a 1 : 1 ethanol-ether mixture in a soxhlet apparatus.

Results

Table I summarises the seasonal variation in the fat content of the liver and gonads in Panulirus, while Table II gives the same for Palaemon. During the months of May, June, July and August specimens of Panulirus could not be obtained in sufficient numbers as these months represented the off-season in its fishery. The figures for February, March and April could not be provided for Palaemon as specimens were not freely available during this period. Again the records obtained during the period September to January were confined to the males as female specimens were not forthcoming at the time.
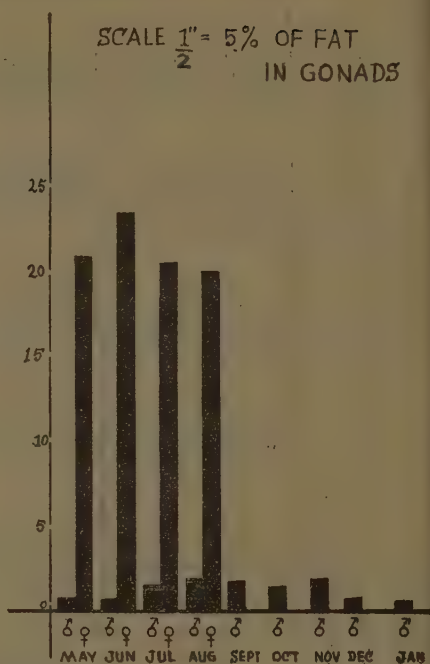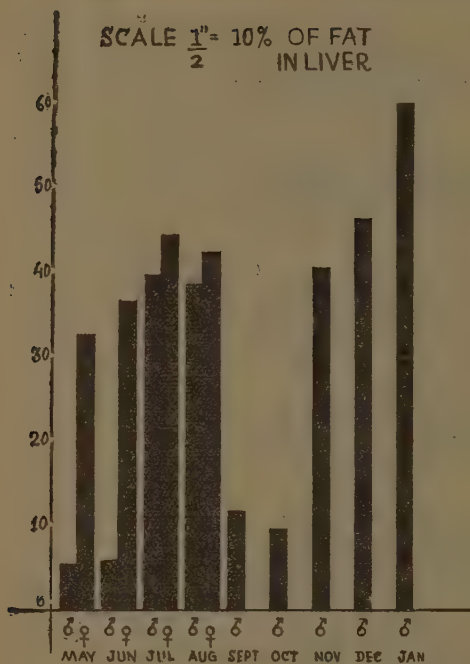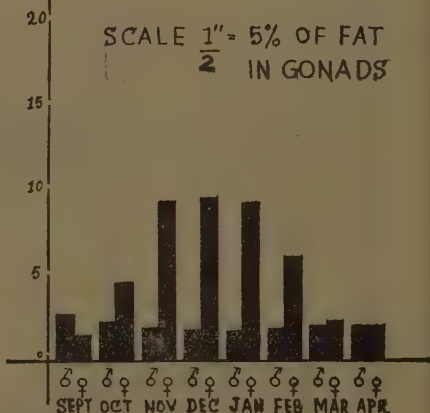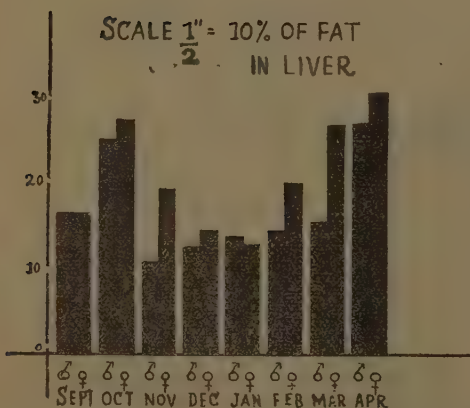
Table No. I

Seasonal variation in the water and the fat contents of the hepatopancreas (liver) and the gonads of the marine lobster, *Panulirus polyphagus*.

Month	Sex	Percentage of water in liver	Percentage of total solids in Liver	Percentage of fat in liver	Percentage of water in Gonads	Percentage of total solids in Gonads	Percentage of fat in Gonads
1	2	3	4	5	6	7	8
September	Male	71.94	28.06	16.43	82.26	17.74	2.60
	Female	70.32	29.68	16.50	91.40	8.60	1.40
October	Male	50.20	29.80	25.00	78.02	21.88	2.20
	Female	61.09	38.91	27.40	68.90	31.10	4.50
November	Male	72.92	27.09	10.72	84.12	15.88	1.75
	Female	67.72	32.28	19.22	58.56	41.44	9.34
December	Male	74.16	25.84	12.42	82.78	17.22	1.63
	Female	67.20	32.80	14.16	40.88	50.12	9 50
January	Male	71.05	28.95	13.80	83.81	16.19	1.75
	Female	73.25	26.75	12.87	66.00	34.00	9.20
February	Male	65.10	34.90	14.59	84.00	16.00	1.83
	Female	60.00	40.00	20.07	70.80	29.20	6.07
March	Male	68.58	31.42	15.54	80.06	19.94	1.92
	Female	59.54	40.46	26.92	76.68	23.32	2.31
April	Male	55.38	44.62	27.02	76.36	23.64	1.96
	Female	50.00	50.00	30.60	75.87	24.13	2.00
May	Not available						
June	,,						
July	,,						
August	,,						

Table No. II

Seasonal variation in the water and fat contents of the hepatopancreas (liver) and the gonads of the fresh water prawn, *Palaemon carcinus.*

Month	Sex	Percentage of water in Liver	Percentage of total solids in Liver	Percentage of fat in Liver	Percentage of water in Gonads	Percentage of total solids in Gonads	Percentage of fat in Gonads
1	2	3	4	5	6	7	8
May	Male	77.71	28.29	5.38	88.80	11.00	0.66
	Female	54.00	46.00	32.60	38.00	62.00	20.90
June	Male	77.06	29.90	5.80	91.30	8.70	0.59
	Female	52.68	47.32	36.62	35.00	65.00	23.50
July	Male	50.30	49.70	39.80	86.57	13.43	1.50
	Female	50.65	49.35	44.26	44.00	56.50	20.50
August	Male	53.37	46.63	38.54	85.09	14.91	1.95
	Female	40.00	60.00	42.33	43.74	56.26	20.00
September	Male	74.15	25.85	11.72	84.34	15.86	1.65
October	Male	80.90	19.10	9.56	86.10	13.90	1.35
November	Male	43.51	56.49	40.60	84.42	15.58	1.67
December	Male	45.40	54.60	46.60	88.00	12.00	0.60
January	Male	32.79	67.21	59.91	88.06	11.94	0.50
February	Not available	—	—	—	—	—	—
March	"	—	—	—	—	—	—
April	"	—	—	—	—	—	—

Histograms showing the seasonal variation in the fat content of the liver and gonads in Palaemon and Panulirus.

Discussion

In the lobster Panulirus the percentage of fat in the liver during April was 27.02 in the male and 30.60 in the female.   The corresponding figures for January were 13.80 and 12.87 respectively—really a low level. The figures for February and March are intermediate.   The conclusion to be drawn from these figures of fat in the liver is that a process of storing fat starts in January and reaches its culmination in April.   The period from January to April has to be looked upon as a fattening period for lobster when it stores up a good deal of reserve fat in its liver.

From the month of May specimens become rare and they reappear in sufficient numbers only in September.   The figures for fat in the liver during September are considerably low being 16.43 in the male and 16.50 in the female.   It may be reasonably surmised that during the interval from May to August when a sufficient number of specimens was not forthcoming, fat was being utilized for metabolic purposes.   From the fact that lobsters are not available during the period from May to August and that the fat content dwindles to a low figure in the liver in September, it may be concluded that lobsters undergo a comparatively dormant period from May to August when there is no active feeding, but the reserve in body is drawn upon.

The period extending from October to January is an active period for the lobster, when specimens are available in large numbers.   During this period the fat content of the liver is varying.   It is 25% and 27% in October, but goes down to 14% and 13% in January.   But the fat content of the female gonads goes from 4.5% in October to 9% in January, while that of the male gonads is slightly reduced in amount.   As a matter of fact the fat content of the male gonads does not undergo any marked fluctuation, from month to month.

In the case of the prawn Palaemon, the three well-defined periods do not, however, exist.   The period from May to August which is the dormant season in the case of Panulirus, becomes the active time in Palaemon.   During May to August both females and males are available in large numbers.   From September onwards till April females disappear from the catch and so far it has not been found possible to find an explanation for their disappearance.   One probability is that they retreat into crevices in deep waters and cannot be induced to stir out.   It may

therefore be assumed that the long gap from April to September corresponds to the fattening and resting periods met with in the case of Panulirus. The males, however, are available from September to January and the amount of fat in the liver increases till it reaches the high figure of about 60%. The progress from about 10% in October to 60% in January in the case of the male is remarkable and this period might be regarded as the fattening period in the case of this crustacean.

One general conclusion to be drawn from this study is that fat store is utilized for the development of eggs only in the female, but as a reserve material in both the sexes.

Another remarkable conclusion to be made is the relatively greater range in the amount of fat met with in the liver of the freshwater decapod in comparison with the marine one. How far this conclusion is universally applicable is not known. The percentage of fat in the liver of the lobster varies from 10.72 to 30.60 whereas the corresponding figures in Palaemon are 5.38 to 59.91

Summary

1. In the case of both the decapods, Panulirus and Palaemon there is a period of scarcity of specimens. The number of Panulirus specimens in the market dwindles down to a few from May to August, and Palaemon from February to April. Moreover, in the case of the latter the specimens available from September to January are predominently male, females being only very very few.

2. From the non-availability of specimens during certain periods of the year it is presumed that these crustaceans at the time retreat to deeper waters or crevices in rocks and exist there in a state of comparative dormancy.

3. Apart from the resting period, two other more or less clearly demarcated physiological periods are also discernible, an active period of feeding and reproduction and a period of fattening. In the case of Panulirus these periods extend respectively from October to January and February to April. In the case of Palaemon the corresponding periods are from May to August and from September to January. In the case of the female Palaemon, however, the fattening and resting periods are not

individually separable on account of the unavailability of female specimens from September to January.

4. From the figures available it is found that fat is utilized in the female for the development of eggs, but not conspicuously so in the development of sperms. It is stored up in both males and females as a reserve material.

5. The range of liver fat in Panulirus is from 10.72% to 30.60%, while it is considerably more in the freshwater Palaemon, being from 5.38% to 59.91%.

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